RENAL ACCESS, TRACT DILATATION AND OPERATIVE TIME ARE SHORTER IN PATIENTS UNDERGOING MINI PERCUTANEOUS NEPHROLITHOTOMY (MINI PCNL) UNDER ULTRASOUND GUIDANCE

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ABSTRACT

Introduction: Traditionally, fluoroscopy is used to successfully perform various steps of percutaneous nephrolithotomy (PCNL). Ultrasound has emerged as new imaging modality and reduces renal access, dilatation and operative time.

Objective: To compare the renal access, tract dilatation and operative time in patients undergoing mini percutaneous nephrolithotomy (mini PCNL) using ultrasound and fluoroscopy for imaging.

Methodology: The study was performed from 1st Jan, 2019 to 30th Aug, 2022 in Urology department at Khyber Teaching Hospital, Peshawar, Pakistan. A cross section of 160 patients was included in the study, with 80 cases performed under ultrasound (UG- mini PCNL) and 80 under fluoroscopy guidance (FG- mini PCNL).

Results: In the ultrasound group, the mean age was 49.0 ± 12.40 years. 25 were females and 55 were males with a mean stone burden of 18.4 ± 1.5 mm. While in fluoroscopy group 37 were females and 43 were males with a mean age 48.58 ± 13.0 years and mean stone size of 18.38 ± 1.5 mm. Preoperative parameters were same in both groups. The UG- mini PCNL group had higher success rate of first puncture (73.7% vs 53.7%, P = 0.01). The mean renal access time was shorter (3.2 ± 1.1 min vs 4.1 ± 1.0 min, P = < 0.005) in UG- mini PCNL group. The tract dilatation time was shorter in UG- mini PCNL group compared to FG-mini PCNL group (7.0 ± 1.2 min vs 8.0 ± 1.4 min, P = < 0.005). The operative time was shorter in UG-mini PCNL than FG-mini PCNL group (73.9 ± 7.3 min vs 85.8 ± 5.2 min, P = < 0.005). However, the hospital stay was the same in both groups. There was significantly less mean drop in hemoglobin in UG- mini PCNL group compared to FG-mini PCNL group (1.26 ± 0.4 vs 1.42 ± 0.4, P = 0.02). The stone clearance (87.5% vs 90 %), complications (10 % vs 13.7 %) and ancillary procedures (7.5 % vs 11.2 %) were the same in both groups.

Conclusion: Ultrasound is a safe alternative to fluoroscopy in mini PCNL. The duration of renal tract puncture, dilatation and operative time can be shortened by using ultrasound with effective stone clearance and without higher complication or bleeding rates for renal stones ≤ 20 millimeters.

Keywords: Fluoroscopy, Image guidance, Mini percutaneous nephrolithotomy, Ultrasound.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the recommended first line treatment for complex and larger renal stones (stone burden > 20mm) by European Association of Urology (EAU).

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It is recommended as alternative treatment option for stones between 10 – 20mm when expertise and flexible uretero-renoscopy are not available. This is due to higher stone free rate, safety, cost effectiveness and minimal complication rate (1). Standard PCNL uses instruments between 24-30 Fr. However several smaller nephroscopes have been introduced recently that aim to decrease complications and hospital stay without compromising stone free rate. A mini PCNL uses working sheath ≤ 22Fr and is used for renal stones 10 – 20mm diameter (2).

Traditionally, fluoroscopy is used to successfully perform various steps of PCNL. These steps include percutaneous puncture of the kidney through desired calyx, dilatation of the puncture tract, fragmentation of the stone, confirmation of stone clearance and nephrostomy tube placement (3). The only disadvantage with fluoroscopy is radiation exposure and real time mono-axial imaging that is time consuming (4).

Ultrasound has emerged as new imaging modality to overcome the problem associated with fluoroscopy. It is cost effective, enables real-time bi-axial image acquisition and avoids radiation exposure (5). However, its utilization in PCNL is limited to few centers as it is not incorporated in urological training (6). Although ultrasound is used in children during mini PCNL, but the data for mini PCNL under complete ultrasound guidance for adult population is limited (7). Our study will not only add evidence to the existing literature but will also pave the way for adding ultrasound guided access in PCNL during urologist training.

We hypothesized that ultrasound guided renal access and dilatation should be quicker than fluoroscopic guided access and dilatation thus reducing operative time. This is based on the fact that imaging with portable ultrasound is bi-axial, allows better stone localization and percutaneous access in real time, and saves adjustment-readjustment time of fluoroscope. Further, the facility of Doppler technique can identify blood vessels and guide safe access into kidney. This study shows the use of ultrasound as imaging tool in mini PCNL and comparing its access, tract dilatation and operative time with fluoroscopic guided mini PCNL.

MATERIALS AND METHODS

This study was conducted from 1st January, 2019 to 30th Aug 2022, in a tertiary care center. Approval was taken from ethical review committee. The sample size was calculated by taking confidence interval of 90% with anticipated population proportion of 0.95, absolute precision of 0.03 and lost to followup rate of 11%. Therefore, the required sample size of this study was estimated to be 158 patients (3). We enrolled a cross section160 consecutive cases (80 cases in each group) after informed consent. We included all patients having age between 18 to 70 years, with single renal or proximal ureteral stone ≤ 20 mm. Patients with congenital renal anomalies, uncorrected coagulopathy, urinary tract infection, history of open renal stone surgery on ipsilateral side, patients with baseline creatinine > 2mg/dl even after percutaneous nephrostomy placement, staghorn stones, multiple calyceal stones without hydronephrosis and pregnancy were excluded from the study. All patients had preoperative non contrast computed tomography scan (NCCT). The renal anatomy, hydronephrosis, site of stone and the anatomy of surrounding structures with respect to the desired access tract was determined on NCCT. All the cases were performed by a consultant urologist.

SURGICAL TECHNIQUE

Preoperative antibiotics were given to all patients. A ureteric catheter was placed retrogradely in both groups in lithotomy position. The position was then changed to prone. In UG-mini PCNL) group, ultrasonography was performed using a 3.5-mhz convex transducer ((Hitachi Aloka Medical, Japan) to identify the location of the desired kidney, stone, and puncture site. A normal saline was injected through ureteral catheter to create physiologic hydronephrosis and confirm successful puncture via 18 gauge access needle. After the puncture, the needle obturator was removed but sheath left in place. A normal saline was infused through the ureteral catheter. The free outflow of normal saline from the needle sheath confirmed the presence of the needle in the desired calyx. A hydrophilic coated angle tip 0.035 inch guide-wire (Terumo Glide-wire, USA) was placed in the same calyx. The fascial dilator, olive tip and metal telescopic dilators all were marked according to depth of the needle. In the fluoroscopy guided mini percutaneous nephrolithotomy (FG-mini PCNL) group, the desired calyx was punctured using bull's eye technique after injecting contrast through the ureteric catheter. In both groups tract was dilated upto 18Fr and 20 Fr Amplatz sheath was used for delivery of 18 Fr nephroscope into the kidney. Stones were fragmented by pneumatic lithoclast and stone fragments were removed by forceps and normal saline wash through Amplatz sheath. The procedure was continued until no stone could be identified by nephroscopic inspection and ultrasound image in UG-mini PCNL. The stone clearance was reconfirmed with one shot fluoroscopy in both UG-mini PCNL and FG-mini PCNL cases at completion of procedure. A 6 Fr JJ stent was placed according to surgeon's discretion. A hand pressure was applied to access tract for 3- 5 minutes to tamponade the access tract without a nephrostomy tube.

Intraoperative parameters like number of attempted renal punctures, renal access time (time elapsed from initial renal imaging to successful needle entry into the collecting system), tract dilation time (time elapsed from wire insertion into the collecting system to advancement of Amplatz sheath over the metal telescopic dilators), total operative time (time elapsed from initial cystoscopy for ureteral catheter placement until nephrostomy tube placement) were recorded. Patients were usually discharged on 2nd or 3rd post-operative day and were followed after one month in outpatient department. Plain x-ray kidney ureter and bladder and ultrasound were done on the same follow up day. Absence of stone or stone fragments ≤ 4mm on plain X-ray KUB and ultrasound was defined as successful stone clearance according to Somani et al (8). It was followed by removal of double J stent.

All complications within 30 days after mini-PCNL were recorded according to the Clavien-Dindo classification system (9). Patients who needed ancillary procedure were followed for another month for stone clearance with the same protocol of imaging.

STATISTICAL ANALYSIS

We compared demographics, characteristics of stone, operative and postoperative outcomes of both groups. Continuous variables were compared using Student-t test. While the Pearson chi-square test or ANOVA test was used for categorical variables. Univariate and Multivariate analysis was performed to remove the effect of confounders on preoperative, intraoperative and postoperative parameters. The IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA) was used for statistical analyses. A p-value ≤ 0.05 was taken as statistically significant.

RESULTS

Final analysis included 160 consecutive patients; with 80 cases performed under ultrasound and 80 under fluoroscopy guidance (3 patients were excluded due to conversion from UG-mini PCNL to FG-mini PCNL while 9 patients were lost to follow in specified duration).

Table 1 shows baseline demographics of both groups. Most of the parameters for both groups were similar at baseline.

TABLE 1: The Patients' Demographics and preoperative clinical characteristics

Characteristics		UG-PCNL N = 80 (%)	FG-PCNL N = 80 (%)	P value
Age ± SD		49 ± 12.40	48.58 ± 13.0	0.8
Gender	Male	55 (68.7)	43 (53.7)	0.07
	Female	25 (31.2)	37 (46.2)	
BMI ± SD		26.77 ± 3.60	26.35 ± 3.77	0.4
Comorbidities	DM	25 (31.2)	21 (26.2)	0.4
	HTN	22 (27.5)	30 (37.5)	0.2
ASA	ASA I	45 (56.2)	48 (60.0)	0.3
	ASA II	30 (37.5)	23 (28.7)	
	ASA III	5 (6.2)	9 (11.2)	
Laterality	Right	32 (40.0)	44 (55.0)	0.08
	Left	48 (60.0)	36 (45.0)	
Stone burden ± SD (mm)		18.4 ± 1.5	18.3 ± 1.5	0.6
Obstruction	Non to Mild	29 (36.2)	37 (46.2)	0.26
	Moderate to severe	51 (63.7)	43 (53.7)	
Preoperative Hb ± SD (g/dL)		13.46 ± 1.12	13.34 ± 1.09	0.4

Values are presented as mean ± standard deviation or number (%).

Chi sq test for categoric variables

Student t-test for numeric variables

The operative and postoperative outcomes are shown in Table 2. The most common pole used for access was the lower pole in both UG-mini PCNL and FG-mini PCNL groups (57.5 % vs 53 .7% respectively). The UG-mini PCNL group had significantly higher success rate of first puncture, shorter mean renal access time, shorter mean tract dilatation time, shorter mean operative time and less mean hemoglobin drop than FG-mini PCNL group. However, the mean hospital stay was the same in both groups.

There stone clearance, complications and ancillary procedures were same in both groups. The overall stone clearance at two months was 93.7% in UG-mini PCNL group. The overall stone clearance in FG-mini PCNL group was 96.2% after two months.

Table 2: Operative and postoperative characteristics

Characteristic		UG-PCNL N = 80 (%)	FG-PCNL N = 80 (%)	P- value
Puncture calyx	Lower	46 (57.5)	43 (53.7)	0.8
	Middle	26 (32.5)	30 (37.5)	
	Upper	8 (10.0)	7 (8.7)	
Puncture attempts	Single	59 (73.7)	43 (53.7)	0.01
	Two or multiple	21 (26.2)	37 (46.2)	
Access time ± SD (min)		3.2 ± 1.1	4.1 ± 1.0	< 0.005
Dilatation time ± SD (min)		7.0 ± 1.2	8.0 ± 1.4	< 0.005
Operative time ± SD (min)		73.9 ± 7.3	85.8 ± 5.2	< 0.005
Hospital stay ± SD (days)		2.7 ± 0.7	2.7 ± 0.7	0.4
Haemoglobin drop ± SD (g/dl)		1.26 ± 0.4	1.42 ± 0.4	0.02
Stone clearance at 1 month		70 (87.5)	72 (90)	0.8
Complications		9 (10.0)	11 (13.7)	0.26
	Clavien grade I	3	5	
	Clavien grade II	4	3	
	Clavien grade IVa	2	3	
Ancillary procedure		6 (6.6)	9 (7.6)	0.5
	URS	2	3	
	ESWL	1	2	
	Medical expulsive therapy	3	4	
Over all Stone clearance at 2 months		75 (93.7)	77 (96.2)	0.4

Values are presented as mean ± standard deviation or number (%).

Anova test for quantitave variables

Chi square test for categoric variables

DISCUSSION

Mini PCNL is increasingly performed by urologists for renal stones ≤ 20 mm due to higher stone free rate, shorter operative time, lower rate of ancillary treatment, cost effectiveness and minimal complication rate as compared to retrograde intra-renal surgery (10). Most of the practicing urologists were trained using fluoroscopy for imaging during PCNL (11). Recently, ultrasound has emerged as alternative imaging tool for PCNL as it is not associated with radiation exposure, enables biaxial real time imaging, and shows the path and depth of puncture needle and anatomy of kidney with surrounding structures (12). However, the identification of kidney, desired calyx, visualization of needle and guidewire are the critical steps that should be successfully achieved. Only then it is possible to proceed with the fascial dilator, olive tip and metal telescopic dilators. Another difficult step is placement of the Amplatz sheath over the telescopic metal dilators.

The lower pole calyx is the most common site of puncture in both groups in our study to avoid pleural injury. Raza et al; reported 2.8% and 3% rate of hydrothorax respectively through upper pole puncture in FG-PCNL (13). We successfully punctured desired calyx in UG-mini PCNL group in first attempt with shortest access and dilatation time. This can be explained by multiple factors. Firstly, factors inherent to ultrasound (continuous real time image, visualization of adjacent soft tissue structures). Secondly, operator related factors include easy identification of posterior clayx, enabling the operator to adopt a straight and shortest path to collecting system. Thirdly, patient related factors like low BMI, dilated collecting system without congenital abnormalities.

Majority of our patients had moderate to severe hydronephrosis in both groups. Therefore we did not face any difficulty in renal access as is reported by Gamal et al in ultrasound guided PCNL in non hydronephrotic kidneys (14). Usawachintachit et al demonstrated that patients with a BMI > 30 kg/m2 had more failed access attempts than patients with lower BMI under ultrasound. Therefore fluoroscopy should be available as alternative imaging for obese patients (15).

Usawachintachit et al reported significantly shorter renal access time, shorter renal dilatation time and shorter total operative time in standard UG-PCNL as compared to FG-PCNL (16). Our results also show significantly shorter renal access time, shorter renal dilatation time and shorter total operative time when ultrasound was used in comparison to fluoroscopy in mini PCNL. The more hemoglobin drop in FG-mini PCNL may be attributed to the longer operative time and bull's eye technique as reported by Tepeler et al in standard PCNL (17).

The stone clearance rate in both UG-mini PCNL and FG-mini PCNL was 87.5 % vs 90% respectively at one month. The overall stone clearance at 2 months after ancillary procedure was even higher with no difference (93.7% vs 96.2 %). Basiri et al found no difference in the stone clearance in a randomized trial of ultrasound and fluoroscopy guided access (79.0% and 65.2%) after one session of standard PCNL (18). This shows that ultrasound is as effective alternative imaging as fluoroscopy with successful stone clearance in mini PCNL. The higher stone clearance rate in our study may be due to higher number of simple renal stones, use of ultrasound and X- ray KUB for imaging instead of low dose Non contrast CT Scan and taking ≤ 4mm stone fragments as definition of stone clearance. Non contrast CT scan may have decreased the stone clearance rate but we did not use this modality as it is costly. The complication rate in our study was low and similar between both groups.

The strengths of our study are that all surgeries were performed by a single urologist which eliminated inter surgeon bias. We are able to produce data on the safety of mini PCNL under ultrasound with shorter renal access, tract dilatation and operative time.

The limitations in our study are its single center data and use of ultrasound and X-ray for stone clearance during follow up which may have increased stone clearance rate as described earlier.

CONCLUSION

In conclusion, the duration of renal tract puncture, dilatation and operative time can be shortened by using ultrasound with effective stone clearance and without higher complication or bleeding rates for renal stones ≤ 20 mm. In future multicenter studies with larger sample size, centered on improving dilatation techniques and instrumentation could be more helpful in clinical decision and improving outcomes.

DECLARATIONS

Authors Contribution

Hazratullah: Questionnaire design, data analysis, data interpretation, drafting.

Nasir Khan: Study design and concept, literature search, data analysis, data interpretation, drafting.

Ahsan Rafi: Questionnaire design, data collection, literature search, drafting.

Conflicts of interest: None declared

Funding: None declared

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